

ENGLISH  
TRANSLATION  
OF INTERNATIONAL  
APPLICATION AS FILED

## DESCRIPTION

### VOLTAGE DETECTING CIRCUIT AND BATTERY DEVICE USING SAME

#### TECHNICAL FIELD

[0001] The present invention relates to a voltage detecting circuit for detecting the voltage of a battery or the like and outputting a signal that indicates whether this voltage is high or low with respect to a predetermined voltage, and to a battery device suitable for battery-mounted equipment that is able to fully utilize the potential of a battery.

#### BACKGROUND ART

[0002] Patent Document 1 discloses one example of a known conventional voltage detecting circuit and battery device using this circuit. Fig. 4 of this example shows a voltage detecting circuit and battery device using this circuit. A battery device 101 includes a voltage detecting circuit 102, series-connected resistors 104, 105, having one end grounded, for generating an input voltage  $V_{BAT}$  of the voltage detecting circuit 102, and a battery 103 connected to the other end of the series-connected resistors that serves as the power source of a battery-mounted equipment. The voltage of the battery 103 is

divided by the series-connected resistors 104, 105, and this divided voltage is input into the voltage detecting circuit 102 as an input voltage  $V_{BAT}$ . The voltage detecting circuit 102 compares the input voltage  $V_{BAT}$  with a detection threshold value voltage  $V_{TH}$ . When the input voltage  $V_{BAT}$  is higher than the detection threshold value voltage  $V_{TH}$  it judges there to be a battery residual quantity available and outputs a high-level voltage as a detected result from an output terminal OUT. Conversely, when the input voltage  $V_{BAT}$  is lower than the detection threshold value voltage  $V_{TH}$ , it judges there to be no battery residual quantity available and outputs a low-level voltage as a detected result from the output terminal OUT. The output terminal OUT is connected to other electronic components (not shown in the drawing) which are included in the battery-mounted equipment.

[0003] The voltage detecting circuit 102 includes a threshold value voltage generator 112 that selectively generates separate different threshold value voltages (high-side and low-side) depending on whether the input voltage  $V_{BAT}$  rises (changes from low voltage to high voltage) or whether it drops (changes from high voltage to low voltage), a comparator 111 that compares this threshold value voltage (detection threshold value voltage  $V_{TH}$ ) with

the input voltage  $V_{BAT}$ , an inverter 124 that inverts the output of the comparator 111, an output switching element 113 that receives the output of the inverter 124 and outputs the voltage detection result from the output terminal OUT, and a reference voltage generator (REF) 114 that generates a reference voltage  $V_{REF}$ . The output of the inverter 124 is also used for selecting of the two threshold value voltages in the threshold value voltage generator 112. The reference voltage  $V_{REF}$  is used as a reference for these threshold value voltages.

**[0004]** The threshold value voltage generator 112 and comparator 111 afford the hysteresis of the input voltage detection. By virtue of this, when the input voltage  $V_{BAT}$  approximates the detection threshold value voltage  $V_{TH}$ , the repeated turning ON and OFF of the output switching element 113 caused by minute levels of noise resulting in instability of the output of the output terminal OUT is prevented.

**[0005]** Patent Document 1: Japanese Patent Application  
Laid-Open No. H11-258280

DISCLOSURE OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0006] The battery device 101 selects the high-side threshold value voltage when the input voltage  $V_{BAT}$  rises and selects the low-side threshold value voltage when it drops. Accordingly, when the battery 103 is removed, as the input voltage  $V_{BAT}$  drops, the low-side threshold value voltage is set as the detection threshold value voltage  $V_{TH}$ . When the battery 103 is then refitted, as the input voltage  $V_{BAT}$  rises, the high-side threshold value voltage is set.

[0007] Fig. 5 shows the relationship between the input voltage  $V_{BAT}$  and the detection threshold value voltage  $V_{TH}$ . The drawing shows a case in which there is only a little residual battery quantity available, that is to say, a case in which the battery voltage has gradually dropped from a state in which the input voltage  $V_{BAT}$  exceeds a high-side threshold value voltage (for example, 2.9V) in the initial usage period of the battery 103 to a state in which the input voltage  $V_{BAT}$  is a voltage (for example 2.6V) between the high-side threshold value voltage and a low-side threshold value voltage (for example 2.5V). When the battery 103 is removed and the input voltage  $V_{BAT}$  drops and intersects the low-side threshold value voltage, the output

terminal OUT switches from the high level to the low level and the detection threshold value voltage  $V_{TH}$  is set to the high-side threshold value voltage. When the battery 103 is then refitted subsequent to the input voltage  $V_{BAT}$  having reached the ground potential (0V), the input voltage  $V_{BAT}$  rises up and exceeds the low-side threshold value voltage value. However, it does not reach and does not intersect with the high-side threshold value voltage and, as a result, the output terminal OUT remains at the low level. Accordingly, while the battery-mounted equipment operates as if residual battery quantity is available until the battery 103 is removed, when the battery 103 is temporarily removed and then refitted, a phenomenon in which there is a state of no residual quantity of the battery 103 available established which prevents the battery-mounted equipment from being started up is produced. This precludes the battery-mounted equipment from being able to be used to the limit of the available residual quantity of the battery 103 and reduces the usable time of the battery.

**[0008]** With the foregoing in view, it is an object of the present invention to provide a voltage detecting circuit in which a battery assembled in battery-mounted equipment can be used with certainty until its usage limit, and to a battery device using this circuit.

#### MEANS FOR SOLVING THE PROBLEM

[0009] In order to resolve the problem described above, the voltage detecting circuit according to a preferred embodiment of the present invention comprises: an input voltage comparing circuit that controls the opening and closing of an output switching element in response to an output of the comparison of a first threshold value voltage or second threshold value voltage lower than the first threshold value voltage with an input voltage, and selects the second threshold value voltage when the input voltage changes from a low voltage to a high voltage and intersects the first threshold value voltage and selects the first threshold value voltage when the input voltage changes from the high voltage to the low voltage and intersects the second threshold value voltage; and a threshold value voltage forcibly setting circuit that compares a third threshold value voltage lower than the second threshold value voltage with the input voltage and, when the input voltage changes from a low voltage to a high voltage and intersects the third threshold value voltage, outputs a pulse for a predetermined period thereafter so that the second threshold value is forcibly selected in the input voltage comparing circuit, the second threshold value

voltage being compared with the input voltage in the input voltage comparing circuit when the input voltage rises up.

[0010] It is preferable that the threshold value voltage forcibly setting circuit select a fourth threshold value voltage lower than the third threshold value voltage when the input voltage changes from a low voltage to a high voltage and intersects the third threshold value voltage, and that it select the third threshold value voltage when the input voltage changes from a high voltage to a low voltage and intersects the fourth threshold value voltage.

[0011] The battery device according to another preferred embodiment of the present invention comprises the above-described voltage detecting circuit; series-connected resistors, having one end grounded, for generating the input voltage of the voltage detecting circuit; and a battery that is connected to the other end of the series-connected resistors.

#### EFFECTS OF THE INVENTION

[0012] According to the preferred embodiment of the present invention, because the voltage detecting circuit and battery device using this circuit use a third threshold value voltage lower than a first threshold value voltage and second threshold value voltage and, when the input

voltage rises up and reaches the third threshold value voltage, a threshold value voltage forcibly setting circuit sets in the input voltage comparing circuit the second threshold value voltage, a battery assembled in battery-mounted equipment can be used with certainty until its usage limit.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0013] [Fig. 1] Fig.1 is a circuit diagram of the voltage detecting circuit according to an embodiment of the present invention and battery device using this circuit.

[Fig. 2] Fig.2 is a circuit diagram of a threshold value voltage generator of Fig. 1.

[Fig. 3] Fig. 3 is an operating waveform diagram of Fig. 1.

[Fig. 4] Fig. 4 is a circuit diagram of a conventional voltage detecting circuit and battery device using this circuit.

[Fig. 5] Fig. 5 is an operating waveform diagram of Fig. 4.

#### EXPLANATION OF REFERENCE NUMERALS

[0014]

- 1 Battery device
- 2 Voltage detecting circuit

3 Battery  
4, 5 Resistors  
7 Input voltage comparing circuit  
8 Threshold value voltage forcibly setting circuit  
13 Switching element  
 $V_{BAT}$  Input voltage  
 $V_{TH}$  Detection threshold value voltage  
 $V_{th1}$  First threshold value voltage  
 $V_{th2}$  Second threshold value voltage  
 $V_{th3}$  Third threshold value voltage  
 $V_{th4}$  Fourth threshold value voltage

BEST MODE FOR CARRYING OUT THE INVENTION

**[0015]** The best mode for carrying out the present invention will be hereinafter described with reference to the drawings. Fig. 1 is a circuit diagram of the voltage detecting circuit 2 according to an embodiment of the present invention and battery device 1 using this circuit.

**[0016]** The battery device 1 includes a voltage detecting circuit 2, series-connected resistors 4, 5, having one end grounded, for generating an input voltage  $V_{BAT}$  of the voltage detecting circuit 2, and battery 3 connected to the other end of the series-connected resistors 4, 5 which serves as the power source of a

battery-mounted equipment. The voltage of the battery 3 is divided by the series-connected resistors 4, 5, and this divided voltage is input as the input voltage  $V_{BAT}$  to the voltage detecting circuit 2. The voltage detecting circuit 2 compares the input voltage  $V_{BAT}$  with a detection threshold value voltage  $V_{TH}$ . When the input voltage  $V_{BAT}$  is higher than the detection threshold value voltage  $V_{TH}$  it judges there to be a battery residual quantity available and outputs a high-level voltage as a detected result from an output terminal OUT. Conversely, when the input voltage  $V_{BAT}$  is lower than the detection threshold value voltage  $V_{TH}$ , it judges there to be no battery residual quantity available and outputs a low-level voltage as a detected result from the output terminal OUT. The output terminal OUT is connected to other electronic components (not shown in the drawing) which are included in the battery-mounted equipment. The resistance value ratio, that is to say, the voltage-dividing ratio of the series-connected resistors 4, 5 is determined by the specification of the electronic components which are included in the battery-mounted equipment. Resistance values are sufficiently large enough to minimize the direct current value.

[0017] The voltage detecting circuit 2 mainly includes an input voltage comparing circuit 7 and threshold value

voltage forcibly setting circuit 8. The input voltage comparing circuit 7, using as a detection threshold value voltage  $V_{TH}$  a first threshold value voltage  $V_{th1}$  or second threshold value voltage  $V_{th2}$  lower than the first threshold value voltage  $V_{th1}$ , controls the opening and closing (ON and OFF) of an output switching element 13 in response to the output of the comparison of the detection threshold value voltage  $V_{TH}$  with the input voltage  $V_{BAT}$ . As well as this, when the input voltage  $V_{BAT}$  rises, that is to say, changes from a low voltage to a high voltage and intersects the first threshold value voltage  $V_{th1}$ , the input voltage comparing circuit 7 selects the second threshold value voltage  $V_{th2}$  as the detection threshold value voltage  $V_{TH}$ , and when the input voltage  $V_{BAT}$  drops, that is to say, changes from a high voltage to a low voltage and intersects the second threshold value voltage  $V_{th2}$ , it selects the first threshold value voltage  $V_{th1}$  as the detection threshold value voltage  $V_{TH}$ . Accordingly, the input voltage comparing circuit 7 imparts hysteresis to the detection input voltage whereupon, when the input voltage approximates the detection threshold value voltage  $V_{TH}$ , the repeated turning ON and OFF of the output switching element 13 is prevented. Then, the instability of output of the output terminal OUT resulting in generation of short-

circuit current or noise in the voltage detecting circuit 2 itself and the electronic components which are included in the battery-mounted equipment is prevented. The output switching element 13 is an N-type MOS transistor of an open-drain configuration that is pulled up to any power source by a resistor (not shown in the drawing) in the outer side of the voltage detecting circuit 2.

[0018] The threshold value voltage forcibly setting circuit 8 compares a third threshold value voltage  $V_{th3}$  lower than the second threshold value voltage  $V_{th2}$  with the input voltage  $V_{BAT}$  and, when the input voltage  $V_{BAT}$  changes from a low voltage to a high voltage and intersects the third threshold value voltage  $V_{th3}$ , outputs a pulse for a predetermined period thereafter, to the input voltage comparing circuit 7 so that the second threshold value voltage  $V_{th2}$  is forcibly selected in the input voltage comparing circuit 7. By virtue of this, when the input voltage  $V_{BAT}$  rises up from the ground potential, the second threshold value voltage  $V_{th2}$  is compared with the input voltage  $V_{BAT}$  in the input voltage comparing circuit 7.

[0019] Furthermore, when the input voltage  $V_{BAT}$  changes from a low voltage to a high voltage and intersects the third threshold value voltage  $V_{th3}$ , the threshold value voltage forcibly setting circuit 8 selects a fourth

threshold value voltage  $V_{th4}$  lower than the third threshold value voltage  $V_{th3}$ , and when the input voltage  $V_{BAT}$  changes from a high voltage to a low voltage and intersects the fourth threshold value voltage  $V_{th4}$ , it selects the third threshold value voltage  $V_{th3}$ . Accordingly, hysteresis is also imparted in the threshold value voltage forcibly setting circuit 8 and, when the input voltage  $V_{BAT}$  approximates the third threshold value voltage  $V_{th3}$ , instability of the output of the threshold value voltage forcibly setting circuit 8 is prevented.

**[0020]** More specifically, the voltage detecting circuit 2 includes an inverter 24 that inverts the output of the input voltage comparing circuit 7, an output switching element 13 that is turned ON and OFF in accordance with the output of the inverter 24, a NOR circuit 23 that controls the input voltage comparing circuit 7 itself based on the input of the output of the input voltage comparing circuit 7 and the output of the threshold value voltage forcibly setting circuit 8, and a reference voltage generator (REF) 14 into which the voltage of the battery 3 is directly input and that generates and outputs a reference voltage  $V_{REF}$ .

**[0021]** The input voltage comparing circuit 7 includes a threshold value voltage generator 12 that selectively

generates a first or second threshold value voltage as the detection threshold value voltage  $V_{TH}$ , and a comparator 11 that compares the detection threshold value voltage  $V_{TH}$  input into an inversion input terminal with the input voltage  $V_{BAT}$  input into a non-inversion input terminal.

**[0022]** The threshold value voltage generator 12, as shown in Fig. 2, includes resistors 31, 32 connected in series between the reference voltage  $V_{REF}$  and ground potential, and a switch 33 provided in parallel with the resistor 31 that is controlled by the input voltage of a terminal CNTLa. The connection point between the resistor 31 and the resistor 32 constitutes an output terminal OUTa that has connection with the inversion input terminal of the comparator 11. The terminal CNTLa has connection with the output of the NOR circuit 23 and is controlled by the output of the input voltage comparing circuit 7 itself and the threshold value voltage forcibly setting circuit 8 as described above. If the voltage of the terminal CNTLa is a high level the switch 33 closes and the reference voltage  $V_{REF}$  is output from the output terminal OUTa as the first threshold value voltage  $V_{th1}$ . If the voltage of the terminal CNTLa is a low level the switch 33 opens and the voltage resulting from the voltage division of the reference voltage  $V_{REF}$  by the resistor 31 and resistor 32 is output

from the output terminal OUTa as the second threshold value voltage  $V_{th2}$ .

**[0023]** Whilst hysteresis of the input voltage  $V_{BAT}$  is afforded in the input voltage comparing circuit 7 by virtue of the threshold value voltage generator 12 and the comparator 11, hysteresis may obviously be afforded by other circuit configurations.

**[0024]** The threshold value voltage forcibly setting circuit 8 includes a second threshold value voltage value generator 16 that selectively generates third and fourth threshold value voltages, a second comparator 15 that compares the third or fourth threshold value voltages input into the non-inversion input terminal with the input voltage  $V_{BAT}$  input into the inversion input terminal, an N-type MOS transistor 17 into which the output of the second comparator 15 is input, a constant current source 18 that has connection to the output of the N-type MOS transistor 17 and at the other end has connection to the reference voltage  $V_{REF}$ , a capacitor 19 that has connection to the output of the N-type MOS transistor 17 and at the other end has connection to the ground potential, an inverter circuit 20 that inverts the output of the N-type MOS transistor 17, an inverter circuit 21 that inverts the output of the second comparator 15, and an AND circuit 22 based on the

inputting of the outputs of the inverter circuits 20, 21 outputs a signal TP to the input terminal of the NOR circuit 23 as described above.

**[0025]** The N-type MOS transistor 17, constant current source 18, capacitor 19 and inverter 20 constitute a circuit that generates a delay (for example, 1 millisecond). This circuit may be replaced by a counter that generates a delay based on the input of a clock that serves as a reference. A pulse of pulse width established by this delay is generated by the circuit that generates this delay, the inverter 21 and the AND circuit 22.

**[0026]** As shown in Fig. 2, the second threshold value voltage generator 16 includes resistors 34, 35, 36 connected in series between the reference voltage  $V_{REF}$  and ground potential, and a switch 37 provided in parallel with the resistor 34 that is controlled by the input voltage of a terminal CNTLb. The connection point of the resistor 35 and resistor 36 serves as an output terminal OUTb and connects to the non-inversion input terminal of the second comparator 15. The terminal CNTLb is connected to the output of the second comparator 15. If the voltage of the terminal CNTLb is a high level the switch 37 closes and the voltage obtained by the voltage-division of the reference voltage  $V_{REF}$  by the resistor 35 and resistor 36 is output

from the output terminal OUTb as the third threshold value voltage  $V_{th3}$ , while if the voltage of the terminal CNTLb is a low level the switch 37 opens and the voltage obtained by the voltage-division of the reference voltage  $V_{REF}$  by the resistor 34 and resistor 35 connected in series and the resistor 36 is output from the output terminal OUTb as the fourth threshold value voltage  $V_{th4}$ .

[0027] As is described above, the imparting of hysteresis by the threshold value voltage forcibly setting circuit 8 is preferable from the viewpoint of preventing instability of the output of the threshold value voltage forcibly setting circuit 8. However, because this output is not output to the exterior of the voltage detecting circuit 2, the extent of short-circuit current or noise generated as a result is not large. Accordingly, the omission thereof may be considered. In this case, the second threshold value voltage generator 16, in the absence of the resistor 34 and the terminal CNTLb shown in Fig. 2, outputs only the third threshold value voltage  $V_{th3}$ .

[0028] The operation of the voltage detecting circuit 2 will be described hereinafter with reference to Fig. 3 specifically indicating the examples of voltage value. When the input voltage  $V_{BAT}$  (for example, 2.6V) is higher than the second threshold value voltage  $V_{th2}$  (for example 2.5V)

serving as the detection threshold value voltage  $V_{TH}$ , the output of the output terminal OUT is a high level and a residual quantity of the battery 3 is judged to be available. When the battery 3 is removed in this state, the input voltage  $V_{BAT}$  drops. When the input voltage  $V_{BAT}$  changes from a high voltage to a low voltage and intersects the second threshold value voltage  $V_{th2}$  (for example 2.5V), the output voltage of the comparator 11 changes from a high to a low level. Subsequently, the output switching element 13 is turned ON to establish the output terminal OUT at the low level and, in addition, the detection threshold value voltage  $V_{TH}$  generated by the threshold value voltage generator 12 changes to the first threshold value voltage  $V_{th1}$  (for example, 2.9V). Although not shown in the drawing, when the input voltage  $V_{BAT}$  drops and the input voltage  $V_{BAT}$  changes from a high voltage to a low voltage and intersects the fourth threshold value voltage  $V_{th4}$  (for example, 2.0V), the output voltage of the second comparator 15 changes from a low level to a high level and the threshold value voltage generated by second threshold value voltage generator 16 becomes the third threshold value voltage  $V_{th3}$  (for example, 2.4V).

**[0029]** The operating of the voltage detecting circuit 2 when the input voltage  $V_{BAT}$  rises up from the ground

potential as a result of the refitting of the battery 3 will be hereinafter described. When the input voltage  $V_{BAT}$  changes from a low voltage to a high voltage and intersects the third threshold value voltage  $V_{th3}$  (for example 2.4V) generated by the second threshold value voltage generator 16, the output voltage of the second comparator 15 changes from a high level to a low level. Subsequently, the N-type MOS transistor 17 is turned OFF and, while the voltage of the capacitor 19 begins to gradually increase from the ground potential due to the current from the constant current source 18, the inverter 20 judges the input as a low level during the delay time (for example, 1 millisecond) determined from the values of the current from the constant current source 18 and the capacitance of the capacitor 19. Accordingly, because the inputs of the AND circuit 22 are both high level the output TP thereof is also a high level, while the output of the NOR circuit 23, irrespective of other input, that is to say, the control signal from the input voltage comparing circuit 7 itself, is a low level. As a result, the detection threshold value voltage  $V_{TH}$  generated by the threshold value voltage generator 12 is the second threshold value voltage  $V_{th2}$  (for example, 2.5V). Accompanying these operations, the threshold value voltage generated by the second threshold

value voltage generator 16 changes to the fourth threshold value voltage  $V_{th4}$  (for example, 2.0V).

[0030] When the input voltage  $V_{BAT}$  further rises and the input voltage  $V_{BAT}$  changes from a low voltage to a high voltage and intersects the second threshold value voltage  $V_{th2}$  (for example 2.5V) during the period of the above delay time (for example, 1 millisecond), the output voltage of the comparator 11 changes from a low level to a high level. Subsequently, the output switching element 13 is turned OFF to establish the output terminal OUT at the high level. In addition, because the input to the NOR circuit 23 is a high level, even after the above delay time (for example, 1 millisecond) has elapsed, the detection threshold value voltage  $V_{th}$  generated by the threshold value voltage generator 12 remains as the second threshold value voltage  $V_{th2}$  (for example, 2.5V). Accordingly, even if the input voltage  $V_{BAT}$  is a lower voltage than the first threshold value voltage  $V_{th1}$  (for example 2.9V), provided the second threshold value voltage  $V_{th2}$  (for example 2.5V) is exceeded, a battery residual quantity is judged as being available.

[0031] On the other hand, if the input voltage  $V_{BAT}$  does not intersect the second threshold value voltage  $V_{th2}$  (for example, 2.5V) during the period of the above delay time (for example, 1 millisecond) even if changing from a low

voltage to a high voltage, the output TP of the AND circuit 22 is established at the low level and the output of the NOR circuit 23 is established at the high level, while the detection threshold value voltage  $V_{TH}$  generated by the threshold value voltage generator 12 returns to the first threshold value voltage  $V_{th1}$  (for example, 2.9V). The output voltage of the comparator 11 remains at a low level and, with the output terminal OUT unchanged at the low level, there is judged to be no residual battery quantity available. The right section of Fig. 3 shows a state where the input voltage  $V_{BAT}$  constitutes a voltage (for example, 2.45V) that has not reached the second threshold value voltage  $V_{th2}$  (for example 2.5V) and there is judged to be no residual battery quantity available.

**[0032]** Although not shown in the drawing, it is notable that the judgment of no available battery residual quantity also includes those instances in which, in the end, even if the input voltage  $V_{BAT}$  does reach the second threshold value voltage  $V_{th2}$  (for example, 2.5V), the rise from the third threshold value voltage  $V_{th3}$  (for example, 2.4V) to the second threshold value voltage  $V_{th2}$  (for example, 2.5V) takes longer than the above delay time (for example, 1 millisecond). Accordingly, for this reason, to prevent the judgment that there is no residual quantity available

despite the battery residual quantity not having reached its usage limit, the above delay time must be determined in advance with consideration of the parasitic capacitance of the battery 3 and resistors 4 and 5 to be greater than the actual time taken from the third threshold value voltage  $V_{th3}$  (for example, 2.4V) to the second threshold value voltage  $V_{th2}$  (for example, 2.5V) when an appropriate battery residual quantity is available.

[0033] As is described above, the voltage detecting circuit 2 according to an embodiment of the present invention and battery device 1 using this circuit is provided with a third threshold value voltage  $V_{th3}$  lower than first and second threshold value voltages  $V_{th1}$ ,  $V_{th2}$  and, because, when the input voltage  $V_{BAT}$  rises up and reaches the third threshold value voltage  $V_{th3}$ , the threshold value voltage forcibly setting circuit 8 sets in the input voltage comparing circuit 7 the second threshold value voltage  $V_{th2}$ , even when the battery of only a little residual quantity available is temporarily removed and then refitted, a phenomenon in which there is a state of no residual quantity of the battery available and in which battery-mounted equipment is prevented from being started up can be prevented. In this way, when the voltage detecting circuit 2 and battery device 1 using this circuit

are assembled in battery-mounted equipment, the battery is able to be used with certainty until the usage limit thereof and the useable time of the battery can be substantially extended.

**[0034]** The present invention is not restricted to the embodiment described above and, within the scope of the items described in the claims, a range of modifications may be made thereto.